when Nebraska and Colorado, for instance, were huge swamps frequented by strange beasts whose fossil remains are now found in the rocks formed from the sand and mud of the ancient swamps, which have since been elevated thousands of feet. The book of 244 pages is as a whole distinctly popular in character.

UNIVERSITY AND EDUCATIONAL NEWS

GOVERNOR DUNNE has signed the bill giving $5,000,000 to the University of Illinois for the biennium. It is the largest grant made in a single law to any university in the United States.

THE University of California has accepted an offer of the Children's Hospital, of San Francisco, whereby the hospital remains independent financially and administratively, but whereby all its resources become available for the educational purposes of the University of California Medical School.

A SEPARATE department of chemical engineering on the same plane as the mining, civil, electrical and mechanical engineering departments will be established in the Columbia graduate engineering school next fall. The head of this department will be Professor Milton C. Whitaker, who has been the professor of engineering chemistry for the past five years. For the past ten years the university has offered courses leading to the degree of chemical engineer in the department of chemistry but the rapidly increasing importance of these industries based upon the applications of chemistry and the subsequent demand for men especially trained, in fundamental engineering problems has led the university to supplement these courses with the more elaborate facilities and opportunities offered in a separate chemical engineering department.

THE new announcement of the West Virginia University states that on and after September 1, 1917, two years of collegiate work, including courses in physics, chemistry, biology and French or German, will be required for admission to the medical school.

THE University of Cincinnati is again giving a pre-medical summer course in physics, analytical chemistry, organic chemistry and zoology. The term lasts from June 7 to August 14, a period of ten weeks.

DR. M. ALLEN STARR has resigned the professorship of neurology at the College of Physicians and Surgeons, Columbia University, and has been succeeded by Dr. Frederick Tilney, Brooklyn.

DR. R. H. GODDARD, instructor in physics at Clark College for the past year, has been made assistant professor.

THE following appointments have been made in the medical faculty of McGill University: Assistant professor of chemistry, Dr. F. W. Skirrow; assistant professor of physiology, Dr. J. A. Gray; associate professor in pathology, Dr. Horst Oertel; assistant lecturer in physiology, Dr. T. P. Shaw; lecturers in immunology, Drs. J. C. Meakins and Fraser B. Gurd; lecturer in hygiene, Dr. R. St. J. Macdonald; lecturer in biology, Dr. F. S. Jackson, and associate professor of physics, Dr. L. V. King.

DR. RICHARD HEYMONS has been appointed professor of zoology in the Berlin School of Agriculture.

DISCUSSION AND CORRESPONDENCE

THE FUNDAMENTAL EQUATION OF MECHANICS

I. IN regard to the question whether $F = ma$ or $F/F' = a/a'$ is the better form in which to introduce the fundamental equation of mechanics, the first point of difference between Professor Hoskins and myself may be stated as follows:[1]

Professor Hoskins's method presupposes, as a matter of common knowledge (in advance of any statement of the fundamental equation), the difficult concept of mass or inertia; while my method postpones the introduction of this concept until the student is in position to define it intelligently in terms of the simpler concepts of force and acceleration.

In an attempt to justify his introduction "at the outset" of the "body-constant," mass,

[1] See Professor Hoskins's article in SCIENCE for April 23, 1915, which was written in reply to an article of mine in SCIENCE for February 5, 1915.

which he dissociates altogether from weight, Professor Hoskins makes use of the time-honored device of defining mass as "quantity of matter." He holds that

the definition (of mass as quantity of matter) has a sufficiently definite meaning, gained from ordinary experience, to be of service in a preliminary explanation of the laws of motion.

This, however, has not always been his opinion. In his excellent treatise on "Theoretical Mechanics,"[2] on page 2, he says:

The mass of a body is often briefly defined as its "quantity of matter." These words, however, convey no definite idea of the meaning of mass as a factor in the determination of motion. A satisfactory definition of mass can not be given in advance of a discussion of the fundamental laws of motion.

This earlier view of Professor Hoskins is precisely the position which I wish to defend. For mass, as a factor in the determination of motion, means the constant ratio of force to acceleration (for example, the statement: "body A has three times the mass of body B" is precisely equivalent to the statement: "body A requires three times as much force as body B to give it a specified acceleration"); and whatever idea the words "quantity of matter" may convey to a beginner's mind, they certainly can not convey this desired idea of mass or inertia until *after* the ideas of force and acceleration, and the idea of the constancy of their ratio for a given body, have been grasped.

Why has Professor Hoskins abandoned this excellent position? The only argument which he advances in favor of the definition of mass as quantity of matter is expressed as follows:

In comparing the masses of bodies composed of one homogeneous substance, the significance of the words "quantity of matter" is indeed readily recognized, and it is distinctly helpful to generalize this notion.

But when one tries to analyze this argument, one runs at once into difficulty. What is the concept which Professor Hoskins here proposes to generalize? In the comparison of bodies composed of one homogeneous sub-

stance, the thing that strikes one as most obvious is that doubling the "quantity of matter" in a body is equivalent to doubling its volume or bulk. Two bricks, we say, contain twice as much clay as one brick. Are we then to understand that it is the notion of *bulk,* which, when properly "generalized," is to lead us to the notion of *mass?*

This can hardly be the interpretation which Professor Hoskins intends. It is true that the notion of bulk is sufficiently familiar, and it is also true that in the case of a homogeneous substance, the mass of a body happens to be proportional to its bulk; but it is surely not true that any correct idea of mass as a factor in the determination of motion can ever be obtained by generalizing the idea of bulk.

What then are we to understand by Professor Hoskins's appeal to the case of homogeneous substance? How does this appeal advance us toward the conception of mass as a factor in the determination of motion? Professor Hoskins's article gives no answer to this question, and I believe that no answer can be given—that in fact the whole attempt to define mass or inertia as "quantity of matter" is utterly vague and futile.

There are, of course, certain contexts in which the term "quantity of matter" is useful. For example, if we start a bonfire in a hermetically sealed box, we may properly say that the "quantity of matter" in the box is the same before and after (for the simple reason that we suppose nothing to have been added and nothing to have escaped). But this tells us merely that for dynamical purposes we may properly treat the contents of the box as *one body,* in spite of any change in size, shape or chemical constitution. It does not tell us anything about the mass of this body. For the mere fact that the quantity of matter in the body is invariable (and this is the only fact about its "body-constant" which can properly be presupposed in advance of some study of inertia) gives us no information whatever about the motion of the body when acted on by a force. Not until we have ascertained by some physical experiment what acceleration is produced in the body (or in some

[2] Second edition, 1903.

equivalent body) by some known force can we predict what acceleration will be produced in the body by any other force. In other words, not until we have applied in some form or other the principle expressed by the equation $F/F' = a/a'$ can we arrive at any practical working knowledge of the mass or inertia of the body, as a factor in the determination of its motion. To say to the beginning student: "Here is a body whose mass is so and so much" simply begs the question, unless he understands how this datum was obtained. The mass or inertia of a body is like its modulus of elasticity; it is physical property to be discovered by experiment, not a metaphysical something to be presupposed as a matter of common knowledge.

In view of those considerations, I can not agree with Professor Hoskins when he says there is no reason for regarding the equation $F/F' = a/a'$ as more "fundamental" than the various other equations mentioned in his paper. The reason seems to me very obvious. The statement of this equation presupposes on the part of the reader a knowledge of the meaning of only three fundamental terms, namely: *body, force* and *acceleration;* while the statements of the other equations presuppose a knowledge not only of these three terms, but also of a fourth term, *mass.* Since the notion of *body* is obviously more elementary than the notion of *body-having-a-given-mass,* the equation $F/F' = a/a'$, which involves only body and not mass, seems to me clearly more fundamental than any of the other equations, and (especially in the form $F/W = a/g$) much more suitable as an introduction to mechanics.

II. A second point of difference between Professor Hoskins and myself concerns the questions of units. According to my method, any units one pleases may be chosen for force, length, and time, and all the other quantities which occur in elementary mechanics are then expressed systematically and naturally in terms of these fundamental units. Hence, as soon as the student has grasped the meaning of the fundamental equation $F/F' = a/a'$, he can proceed at once to the solution of practical problems.[4] On the other method, the student is unable to begin work on the simplest problems in rectilinear motion (such as those treated on page 186 of Professor Hoskins's "Theoretical Mechanics") until after he has mastered a long discussion of various artificially restricted systems of units, with their unfamiliar names like the dyne and the poundal (pages 177–186). This needless restriction on the choice of units is a serious disadvantage to the beginner—a disadvantage which results solely from the insistence on the use of the equation $F = ma$ as the fundamental equation of mechanics, and which disappears altogether when the equation $F/F' = a/a'$ is employed.

In further defense of my contention that the system of units based on *force,* length, and time is more convenient and more natural than the system based on *mass,* length, and time, I may add that this contention is strikingly borne out by the usages of scientific terminology. Even in the C. G. S. system, which is understood to be based on the centimeter, the gram mass, and the second as the fundamental units, the dyne force plays a more important rôle in the naming of the derived units than does the gram mass. For example, the unit of power in this system is the dyne-centimeter per second; the unit of pressure the dyne per square centimeter, etc.; whereas if the gram mass were consistently retained as the fundamental unit, we should have to have 1 gram centimeter^2 per second^3 as the unit of power, and 1 gram per centimeter-second^2 as the unit of pressure! In other words, the awkward attempt to make mass the fundamental and force the derived unit has been practically abandoned in the accepted terminology of pure science. Why should it not be abandoned also in elementary teaching?[5]

[4] See my article in Science for February 5, 1915.

[5] We are not here concerned with the purely technical question as to how the physical standards for the various units may best be preserved to posterity. For purposes of elementary instruction, a standard spring balance representing a unit of force is just as satisfactory as a standard lump of metal representing a unit of mass, in spite

III. In regard to the equation $V = FTg/W$ which has been proposed by Mr. Kent in SCIENCE for March 19, 1915, my feeling agrees with that already expressed by Professor Hoskins in SCIENCE for May 7, 1915, namely, that no equation which covers only the special case of a body starting from rest, under a constant force, and does not involve the idea of mental equation of mechanics. Mr. Kent's paper, however, is not without interest on the pedagogical side.

IV. Finally, in regard to the objections raised by Professor Hoskins to a certain definition of the term "force of gravity" which I gave some years ago (objections which, it should be observed, do not affect the present question as to the choice of the fundamental equation of mechanics), I wish to say that his criticism seems to me well-founded, and that my definition was not happily phrased. The important facts about W and g remain true, however, as follows: If we define the weight, W, of a body, in a given locality, with respect to any given frame of reference, as the force required to support the body at rest with respect to that frame; and if we denote by g the acceleration of the body when allowed to fall freely in the given locality, as measured by an observer on the given frame of reference; then the ratio W/g will always be the correct expression for the mass or inertia of the body, regardless of any motion which the given frame of reference may possess. I hope to revert to this point on some future occasion.

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THE PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES

To THE EDITOR OF SCIENCE: Please be so kind as to print in SCIENCE the following letter which I have addressed, under date of June 17, 1915, to Dr. Arthur L. Day, home secretary of the National Academy of Sciences, Washington, D. C.:

Replying to your request to subscribe to the *Proceedings of the National Academy*, may I voice

of the fact that the latter is much more readily preserved than the former.

a protest which I believe many scientific men share with me, but which few will care to formulate and send to you.

A general scientific society, before which abstruse papers are read on most minute details of specialized scientific work, is an anachronism of the most glaring kind. Certainly, when a large audience endures patiently the reading and discussion of a paper which is entirely beyond the ken and comprehension of nine tenths of them, they are wasting their valuable time, and the whole procedure smacks of the farcical.

Further, when you publish such a miscellany of highly specialized papers in your *Proceedings*, is it fair to any man on earth to ask him to pay for the whole set of papers in order to get the one or two which he can read understandingly and profitably? You surely can not expect a man of understanding to risk acute mental indigestion by trying to assimilate the specialized articles entirely outside of his ability to absorb. Then why should any individual be expected to pay good money for so much material useless to him? Are you not guilty of wasting much good ink and paper, postage and shelf space—a waste which the apostles of true conservation should deplore and discourage?

Still further, modern efficiency in almost all its various shapes is based on pushing as far and as hard as possible in the contrary direction. Concentration of mind and effort towards one goal, elimination of the unnecessary and the distracting, doing one thing mighty well—are the principles of specialization which are at the basis of modern efficiency and achievement. But your society and its *Proceedings* tend towards diffuseness, cumber our minds and steal away our attention with the unnecessary and superfluous, and rob the special societies of papers and discussion which they alone are well fitted to receive and digest. In short, are you not a stumbling block before the wheels of scientific progress, a panderer to scientific charlatanism, rather than a promoter of scientific efficiency?

Let me in all seriousness recommend the abandonment of publication of your *Proceedings*, if not even the cancelling of your scientific sessions. Let the astronomers discuss "Photographic Determination of Stellar Parallaxes" with astronomers, the chemists "Chondrosamine" with organic chemists, the mathematicians "The Straight Lines on Modular Cubic Surfaces" with mathematicians, the zoologists "Ecology of the Murray Island Coral Reef" with zoologists, etc.—for only such special groups